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Anisotropy and enthalpy relaxation of calcium alumosilicate glass fibers

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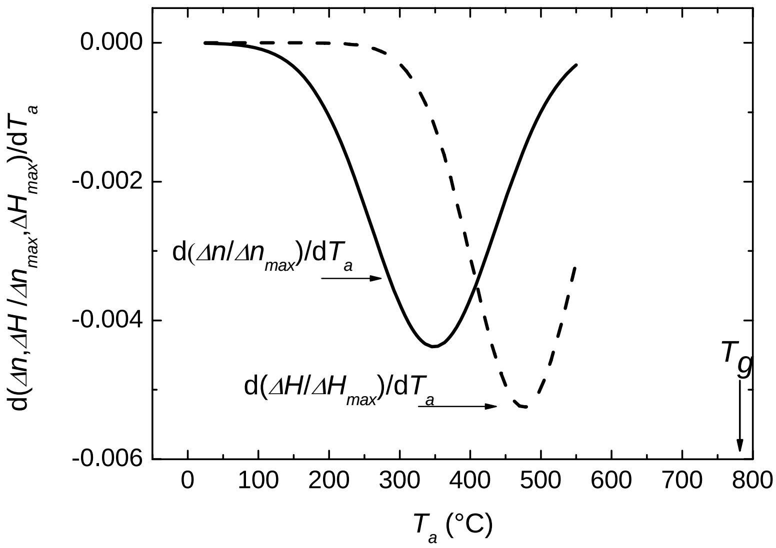
Upon fiber drawing, a silicate melt is thermally quenched and mechanically stretched. Cooling rates >10^6 K/min of quenched glass fibres lead to higher enthalpy state of liquids, thereby, to higher fictive temperature than regular quenching (e.g. 20 K/min) of bulk glass products [1], whereas stretching results in structural anisotropy of glasses, i.e. a certain degree of preferred structural orientation along the axial direction of the fibers, which is quantified by the optical birefringence [2].
Optical birefringence and calorimetric studies have been conducted with respect to structural relaxation of calcium alumosilicate glass fibres. Simultaneous relaxation of both anisotropy and excess enthalpy (relative to the enthalpy of a glass cooled at the standard rate of 20 K/min) upon static annealing and dynamic heating is observed, both of which can be described using the Kohlrausch function. However, there is a striking difference between the birefringence and the excess enthalpy relaxations. The birefringence decays much faster than does the excess enthalpy, i.e. the temperature at which relaxation is fastest, is located for the excess enthalpy at 475°C (≈ $0.71T_g$) and for the birefringence at 348°C (≈ $0.59T_g$), indicating that anisotropy is much more unstable than the excess enthalpy during annealing (Fig.) [3]. These observations also imply that the birefringence decay results from fast relaxation of local structure, while the enthalpy relaxation results from slow relaxation of larger domains of the network.

Fig.:
First temperature derivative of the anisotropy relaxation index ($\Delta n/\Delta n_{max}$) and the enthalpy relaxation index ($\Delta H/\Delta H_{max}$), where ΔH is the remaining amount of the excess enthalpy of the fibers (relative to the enthalpy of the standard-cooled fibers) after a certain degree of annealing (180 min at T_a), and ΔH_{max} is the total excess enthalpy of the fibers before annealing.



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